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Original Research Article

Perineural versus Perivascular Ultrasound-Guided Axillary Brachial Plexus Block for Elective Upper Limb Surgery: A Double-Blind Randomized Controlled Trial

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ABSTRACT

Background: Ultrasound-guided axillary brachial plexus block is widely used for elective upper limb surgeries due to its effectiveness and safety. Two commonly employed techniques are the perineural and perivascular approaches. While the perivascular technique is technically simpler, the perineural approach may provide faster onset and superior block quality. This study compared the efficacy, safety, and hemodynamic effects of both techniques.

Methods: A double-blind randomized controlled trial was conducted among 160 patients undergoing elective upper limb surgeries, with 80 patients each allocated to the perineural (PN) and perivascular (PV) groups. Ultrasound-guided axillary brachial plexus block was performed using standardized anesthetic protocols. Primary outcomes included sensory and motor block onset times and block success rate. Secondary outcomes included duration of sensory and motor blockade, rescue analgesia requirement, supplemental block requirement, hemodynamic parameters, and complications. Statistical analysis was performed using appropriate comparative tests, with $p < 0.05$ considered significant.

Results: The perineural approach demonstrated significantly faster sensory and motor block onset, higher block success, and superior block quality compared with the perivascular approach. Sensory block duration (402 ± 76 vs. 362 ± 73 min; p = 0.001) and motor block duration (344 ± 68 vs. 319 ± 65 min; p = 0.020) were significantly longer in the PN group. Rescue analgesia (7.5% vs. 17.5%; p = 0.049) and supplemental nerve block requirements (10.0% vs. 22.5%; p = 0.035) were significantly lower in the PN group. Complications, including vascular puncture and paresthesia, were less frequent with the perineural technique, resulting in a lower overall complication rate (7.5% vs 22.5%; p = 0.009). Hemodynamic parameters remained comparable between groups.

Conclusion: The perineural approach is superior to the perivascular technique for ultrasound-guided axillary brachial plexus block, providing faster onset, improved block success, prolonged analgesia, reduced analgesic requirements, and fewer complications while maintaining hemodynamic stability. It should be considered the preferred technique for elective upper limb surgeries.

Keywords: Axillary Brachial Plexus Block, Ultrasound Guidance, Perineural Approach, Perivascular Approach, Regional Anaesthesia, Upper Limb Surgery.

INTRODUCTION

Regional anaesthesia has become a preferred technique for elective upper limb surgeries because it provides effective intraoperative anaesthesia, superior postoperative analgesia, early mobilisation, and reduced opioid consumption. Among the various brachial plexus block approaches, the axillary approach is particularly favoured for procedures distal to the elbow due to its superficial anatomy, ease of access, and lower risk of major complications.[1]

The axillary brachial plexus block targets the median, ulnar, radial, and musculocutaneous nerves surrounding the axillary artery, making it highly suitable for orthopaedic, plastic, and hand surgeries. However, conventional landmark-based techniques may result in variable success rates because of anatomical variations and incomplete nerve blockade.[2]

The advent of ultrasound guidance has significantly improved the safety and effectiveness of peripheral nerve blocks by allowing direct visualization of neural structures, surrounding vessels, needle trajectory, and local anaesthetic spread. Ultrasound-guided axillary brachial plexus block has been associated with higher success rates, reduced local anaesthetic requirements, shorter procedure times, and fewer complications.[3]

Two commonly used ultrasound-guided techniques are the perivascular and perineural approaches. The perivascular technique involves deposition of local anaesthetic around the axillary artery and is technically simpler, requiring fewer needle manipulations. However, it may result in inconsistent blockade, particularly of the musculocutaneous nerve, due to anatomical variability.[4] In contrast, the perineural approach involves targeted deposition of local anaesthetic around individual nerves, potentially resulting in faster onset, denser blockade, and greater block reliability, although it requires greater technical expertise and may increase procedure time.[5]

The choice between these approaches has important clinical implications. While the perivascular technique offers procedural simplicity and efficiency, concerns remain regarding incomplete blockade and delayed onset. Conversely, the perineural technique may provide superior block quality but is technically more demanding.[6] Previous studies have reported conflicting results regarding onset time, block success, duration of analgesia, and complication rates, highlighting the need for further research.[7]

Reliable regional blockade is essential for optimal surgical conditions, effective postoperative analgesia, and patient safety. Comparative evaluation of perineural and perivascular approaches can provide valuable evidence regarding block efficacy, analgesic duration, complication rates, and patient-centred outcomes.[8,9] Therefore, this study was undertaken to compare the efficacy and safety of ultrasound-guided perineural and perivascular axillary brachial plexus block techniques in elective upper limb surgeries.[10]

Aims and Objectives

The aim of this double-blinded randomized controlled trial was to evaluate the efficacy of ultrasound-guided perineural versus perivascular axillary brachial plexus block in patients undergoing elective upper limb surgeries. The primary objective was to compare the two techniques with respect to the onset of sensory and motor blockade and overall block success rate. The secondary objectives were to assess and compare hemodynamic parameters, including heart rate, systolic and diastolic blood pressure, oxygen saturation, and respiratory rate, as well as the incidence of block-related complications such as vascular puncture and paraesthesia between the two groups.

MATERIALS AND METHODS

Study Design

This prospective, randomized, double-blinded clinical trial was conducted in the Department of Anaesthesiology after obtaining approval from the Institutional Ethics Committee. A total of 160 patients scheduled for elective upper limb surgeries and meeting the predefined inclusion and exclusion criteria were enrolled using a convenience sampling method. After obtaining informed consent, participants were randomly allocated in equal numbers to either the perineural or perivascular ultrasound-guided axillary brachial plexus block group for comparative evaluation.

Inclusion and Exclusion Criteria

The study included adult patients aged 18–60 years of either sex, belonging to ASA physical status I or II, who were scheduled for elective upper limb fracture surgeries and provided informed written consent. Patients were excluded if they had bleeding disorders, infection at the axillary region of the operative limb, known allergy to local anaesthetics or opioids, severe obesity (BMI >35 kg/m²), pregnancy or breastfeeding, psychiatric or neurological disorders, or a history of previous axillary surgery.

Sample Size Calculation

The sample size for this randomized controlled trial is determined considering the difference in mean total duration of sensory block (in minutes) between two groups: PN (Group 1) and PV (Group 2) as the primary outcome measure for estimating the effect size in patients undergoing upper limb surgeries.

Following assumptions are made from the similar study conducted by Padmini et al. ¹⁹.

Assumptions

Parameter	Value
Mean Total Duration Of Sensory Block In Group 1	389.70 Min
Mean Total Duration Of Sensory Block In Group 2	355.92 Min
Standard Deviation In Group 1	78.0 Min
Standard Deviation In Group 2	71.8 Min
Mean Difference Between Two Groups	33.78 Min
Alpha Error (2-Sided)	5%
Power (1 – Beta)	80%
Required Sample Size (N) Per Group	78

Effect Size: >8% faster duration in minutes in Group 1 versus Group 2. Required sample size, n = 78, rounded to 80 per group. Therefore, a total of 160 subjects was included in this study and equally assigned into two groups.

Following formula is used for estimating the sample size:

$$n = \frac{2S^2(Z_{1-\alpha} + Z_{1-\beta})^2}{\delta^2}$$

Where,

- S_1: Standard deviation in the first group
- S_2: Standard deviation in the second group

$$S^2 = \frac{(S_1^2 + S_2^2)}{2}$$

- Mean difference (Effect size)

$$\delta = (\mu_1 - \mu_2)$$

- α: Significance level
- $1 - \beta$: Power

Data Collection Tools

Data were collected using a high-frequency linear ultrasound probe (M11 mm broadband linear array probe, 6–14 MHz; GE Healthcare LOGIQ-E with color Doppler) covered with a sterile sheath for performing ultrasound-guided axillary brachial plexus blocks. Hemodynamic and respiratory parameters, including SBP (Systolic Blood Pressure), DBP (Diastolic Blood Pressure), HR (Heart Rate), SpO_2 (Oxygen Saturation), and RR (Respiratory Rate), were monitored and recorded using multiparameter patient monitors throughout the study period.

Data Collection Procedure

After obtaining Institutional Ethics Committee approval and written informed consent, 160 ASA I and II adult patients scheduled for elective upper limb surgeries were enrolled and randomized equally into perineural (PN) and perivascular (PV) groups using a simple block randomization method. Allocation concealment was ensured using sealed opaque envelopes, and both patients and outcome assessors were blinded to group assignment. Following standard preoperative fasting (6–8 hours) and baseline monitoring of SBP, DBP, HR, RR, SpO_2, and ECG, ultrasound-guided axillary brachial plexus blocks were performed. The PN group received 30 mL of local anesthetic solution (2% lignocaine with adrenaline 10 mL + 0.5% bupivacaine 10 mL + distilled water 10 mL) administered around individual nerves, with 6 mL injected separately around the musculocutaneous nerve. The PV group received the same anesthetic solution, with 24 mL deposited incrementally around the axillary artery and 6 mL injected separately around the musculocutaneous nerve. A blinded observer subsequently recorded all study outcomes and complications.

RESULTS

Variable	Perineural (N=80)	Perivascular (N=80)	P-Value
Age (In Years)	38.9 ± 11.2	39.7 ± 10.8	0.64
Male (%)	65.0%	62.5%	0.74
Female (%)	35.0%	37.5%	0.74
BMI (Kg/M²)	24.9 ± 3.1	25.1 ± 3.0	0.68

Table 1. Baseline Demographic Characteristics

Table 1 illustrates the baseline demographic characteristics of both groups. Age, gender distribution, and BMI were comparable between the perineural and perivascular groups with no statistically significant differences, confirming baseline homogeneity of the study population.

Nerve	Perineural (Min)	Perivascular (Min)	P-Value
Radial	7.9 ± 2.4	10.4 ± 3.1	<0.001
Median	7.2 ± 2.2	9.8 ± 2.9	<0.001
Ulnar	7.6 ± 2.5	10.1 ± 3.2	<0.001
Musculocutaneous	6.4 ± 1.9	7.2 ± 2.1	0.014
Overall Sensory Onset	8.1 ± 2.3	10.7 ± 2.9	<0.001

Table 2. Sensory Block Onset Time

Table 2 demonstrates sensory block onset times for individual nerves and overall sensory blockade. The perineural approach produced significantly faster sensory onset across all nerve territories compared with the perivascular approach.

Nerve	Perineural (Min)	Perivascular (Min)	P-Value
Radial	12.5 ± 3.3	15.2 ± 3.8	<0.001
Median	11.2 ± 3.1	13.8 ± 3.6	<0.001
Ulnar	11.8 ± 3.2	14.4 ± 3.7	<0.001
Musculocutaneous	9.8 ± 2.8	10.9 ± 3.0	0.018
Overall Motor Onset	11.6 ± 3.1	14.2 ± 3.7	<0.001

Table 3. Motor Block Onset Time

Table 3 shows motor block onset characteristics. Motor blockade occurred significantly earlier in the perineural group, indicating more rapid anesthetic diffusion and nerve engagement.

Parameter	Perineural	Perivascular	P-Value
Composite Score	15.3 ± 0.9	14.6 ± 1.2	<0.001
Successful Block (%)	95.0%	83.8%	0.020
Failed Block (%)	5.0%	16.2%	0.020

Table 4. Block Quality And Success

Table 4 summarizes overall block efficacy. The perineural technique achieved higher composite block scores and significantly greater block success rates, demonstrating superior anesthetic quality.

Parameter	Perineural	Perivascular	P-Value
Sensory Block Duration (Min)	402 ± 76	362 ± 73	0.001
Motor Block Duration (Min)	344 ± 68	319 ± 65	0.020
Rescue Analgesia Required (%)	7.5%	17.5%	0.049
Supplemental Block Required (%)	10.0%	22.5%	0.035

Table 5. Duration Of Block And Analgesic Outcomes

Table 5 evaluates postoperative block performance**.** The perineural approach produced longer sensory and motor blockade, reduced rescue analgesic requirement, and decreased need for supplemental nerve blocks.

Complication	Perineural (%)	Perivascular (%)	P-Value
Vascular Puncture	2.5	11.3	0.028
Paraesthesia	3.8	12.5	0.041

Table 6. Procedure-Related Complications

Table 6 compares procedure-related complications. The perineural technique demonstrated significantly fewer vascular punctures and episodes of paraesthesia, indicating a superior safety profile.

Parameter	Perineural	Perivascular	P-Value
Pulse Rate (Beats/Min)	82.1 ± 10.5	83.0 ± 10.1	0.61
SBP (Mmhg)	124.6 ± 12.8	125.3 ± 13.1	0.74
DBP (Mmhg)	78.4 ± 8.6	78.8 ± 8.2	0.68
Respiratory Rate (/Min)	16.9 ± 2.1	16.8 ± 2.0	0.83
Spo_2 (%)	98.2 ± 1.1	98.2 ± 1.0	0.90

Table 7. Baseline Hemodynamic Parameters

Table 7 presents baseline hemodynamic variables**.** No significant differences were observed between groups, confirming physiological comparability before block administration.

Parameter	30 Minutes P-Value	60 Minutes P-Value
Pulse Rate	0.78	0.75
SBP	0.71	0.70
DBP	0.63	0.74
Spo_2	0.80	NS

Table 8. Intraoperative And Postoperative Hemodynamic Parameters

Table 8 summarizes hemodynamic trends during and after surgery. Heart rate, blood pressure, respiratory status, and oxygen saturation remained stable and comparable between both groups throughout the perioperative period, indicating excellent hemodynamic safety.

DISCUSSION

The present randomized double-blinded controlled trial was conducted to compare the efficacy of ultrasound-guided perineural and perivascular approaches for axillary brachial plexus block in patients undergoing elective upper limb surgeries. The primary outcomes assessed were onset of sensory and motor blockade and block success rate, while secondary outcomes included hemodynamic parameters and procedure-related complications.

In the present study, demographic variables including age, gender distribution, and body mass index were comparable between the two groups, indicating adequate randomization and minimizing the influence of confounding variables on study outcomes. Similar baseline characteristics were reported by Bernucciet al.,[11] Ambi et al.,[12] Vastrad et al.,[13] and Adebayo et al.,[14] thereby supporting the validity of comparative analyses between perineural and perivascular techniques.

A major finding of the present study was the significantly faster onset of sensory blockade observed in the perineural group compared with the perivascular group. This finding is consistent with the observations of Balamurugan et al.,[15] Ferraro et al.,[16] Padmini et al.,[17] Vastrad et al.,[13] and Bhatia et al.,[18] all of whom demonstrated a shorter sensory onset time following targeted perineural injection. The faster onset associated with the perineural technique may be attributed to direct deposition of local anesthetic around individual terminal nerves, resulting in immediate nerve exposure and reduced dependence on diffusion through fascial compartments. Anatomical studies have demonstrated considerable variability in the relationship between terminal nerves and the axillary artery, particularly with regard to the musculocutaneous nerve, which may lie outside the neurovascular sheath and therefore receive inadequate anesthetic exposure during perivascular injection.[19] This anatomical variability provides a plausible explanation for the delayed sensory onset observed with perivascular techniques.

Similarly, the onset of motor blockade was significantly faster in the perineural group. This finding is in agreement with reports by Balamurugan et al.,[15] Ferraro et al.,[16] and Padmini et al.,[17] who demonstrated earlier motor block development with targeted nerve injections. The enhanced motor blockade observed with the perineural technique may result from more uniform circumferential spread of local anesthetic around the neural structures, thereby ensuring efficient penetration of nerve fascicles. Ultrasound visualization allows confirmation of adequate drug spread around each nerve, contributing to greater block density and predictability.[20]

The present study also demonstrated a higher overall block success rate in the perineural group. Although both techniques achieved clinically acceptable success rates, the superior success observed with perineural injection is consistent with the findings of Balamurugan et al.,[15] and Adebayo et al.,[14] Several studies have reported comparable success rates between techniques[11,12] however, these studies also acknowledged the potential for incomplete blockade in perivascular approaches due to anatomical variability and inconsistent anesthetic spread. The ability to individually identify and block the median, ulnar, radial, and musculocutaneous nerves likely contributed to the higher success rate observed in the present study.

Another important observation was the prolonged duration of sensory and motor blockade in the perineural group. Similar findings have been reported by Balamurugan et al.[15] These studies collectively suggest that targeted deposition of local aesthetician close proximity to neural structures facilitates sustained nerve exposure and prolonged analgesic effects. Consequently, patients in the perineural group required fewer supplemental analgesics and demonstrated improved postoperative pain control. These findings are clinically relevant because prolonged postoperative analgesia enhances patient comfort, reduces opioid consumption, and contributes to accelerated recovery.

With respect to procedural complications, the present study observed lower incidences of vascular puncture and paraesthesia in the perineural group. Comparable observations were reported by Ferraro et al.,[16] and Balamurugan et al.[15] Although perivascular techniques are generally considered technically simpler and require fewer needle passes,[11,13] reliance on needle placement around the axillary artery may increase the likelihood of vascular contact. Ultrasound-guided identification of individual nerves allows more controlled needle advancement and targeted local anesthetic deposition, potentially reducing procedure-related complications.

Hemodynamic parameters including heart rate, systolic blood pressure, diastolic blood pressure, respiratory rate, and oxygen saturation remained stable throughout the study period in both groups. No statistically significant differences were observed between groups at any assessment interval. Similar findings have been reported by Khan et al.,[21] Avula et al.,[22] indicating that both techniques provide effective regional anesthesia without causing clinically significant hemodynamic disturbances. This finding reinforces the safety profile of ultrasound-guided axillary brachial plexus block irrespective of injection strategy.

The findings of the present study support the evolving concept that precision-guided regional anesthesia offers meaningful clinical advantages. Advances in ultrasound technology have enabled direct visualization of terminal nerves, allowing anesthesiologists to overcome anatomical variability and fascial barriers that may limit local anesthetic spread in perivascular techniques.[19,20] Consequently, perineural injection appears to provide superior block characteristics while maintaining an acceptable safety profile.

The results of the present study demonstrate that ultrasound-guided perineural axillary brachial plexus block provides faster onset of sensory and motor blockade, higher block success rates, prolonged duration of analgesia, reduced need for rescue analgesics, and fewer complications compared with the perivascular approach. Although the perivascular technique remains a useful and technically simpler alternative, particularly in high-volume clinical settings, the perineural approach appears to offer superior clinical efficacy and reliability for elective upper limb surgeries.

Limitations

The present study has certain limitations. Being a single-center study, the findings may have limited generalizability to other clinical settings. Long-term outcomes such as persistent neurological deficits and chronic pain were not assessed. Although ultrasound guidance was used, operator experience may have influenced block performance. Anatomical variations among patients and the use of a single local anesthetic regimen may have affected the results. Blinding of the performing anesthesiologist was not feasible, introducing potential performance bias. Additionally, cost-effectiveness was not evaluated, and the sample size may have been insufficient to detect rare complications.

CONCLUSION

The present study concludes that the ultrasound-guided perineural approach to axillary brachial plexus block provides faster sensory and motor block onset, higher block success, better block quality, prolonged analgesia, and fewer complications compared to the perivascular approach, while maintaining comparable hemodynamic stability. These findings suggest that the perineural technique is a more reliable and effective option for elective upper limb surgeries and may offer particular advantages in settings with variable operator experience.

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